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Seismic Behaviour of Framed Structure Considering Soil Structure Interaction

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ABSTRACT:Inelastic response of the buildings are often developed without considering soil structure interaction where the base is assumed to be fixed. The present study presents the soil structure interaction and ambiguity effects in soil properties such as Poisson's ratio of the multy storied framed structure in three different types of soil, namely soft, medium and hard soil with fixed and flexible base considering soil structure interaction. In this paper, a model of G+10 storey building with fixed and flexible base considering raft foundation was analysed using SAP2000. From the analysis, it was observed that the results of lateral displacement, storey displacement, base shear, moment values and the time period were on higher side in the flexible base considering soil structure interaction. The requirements of considering soil structure interaction during design of structure can be understood.

KEYWORDS:Soil Structure Interaction, Fixed base, Flexible base, Displacement, Storey drift, Base shear, Axial force, Moment values, Time period, SAP2000.

I. INTRODUCTION

When the soil structure interaction (SSI) is considered during design, the designer has to take several soils, structural and seismic parameters into consideration. Role of foundation needs to be studied with reference to its behaviour for the action of only gravity loading. Under the action of only gravity loading the role of foundation of the structure is to support vertical loads such as dead loads, wall loads etc. of structures. The loads are transferred from the roofs to beam then to column and finally transferring to foundation or ground.

The failure of foundation to match the free movement of ground causes the kinematic interaction between the ground and structure. The seismic vibrations from ground are transmitted to the structure causing displacements of structure. On other hand the mass of structure transmits the inertial forces to the ground modifying the deformations of the ground, which is termed as inertial interaction. Hence these two interactions between the soil and the structural namely, the kinematic interaction and inertial interaction due to seismic activity affect the response of the structural system.

II. SOIL STRUCTURE INTERACTION STUDY

The study if the interaction between structure and supporting system namely, the soil medium is of significance to both geotechnical and structural engineers. Outcomes of such study can be proved decisive in the structural design of the footing, in stress and deflections within the adopted soil medium.

III. SIGNIFICANCE OF THE STUDY

The current review interprets the probable outcomes results in terms of shear, deformation, time period and storey drift in structural members. The comparative study of inelastic reaction of structure considering SSI with fixed base and

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flexible base is tabulated. This project deals with the deformative reaction of structure in various soil conditions, which is identified by stiffness in springs, with consideration of soil structure interaction (SSI).

IV. MODEL STUDIES

The particular building model of G+10 storey, with each storey height of 3m is considered for the project. M30 grade concrete and HYSD 415 grade steel is used for analysis. Masonry infill is modelled with clay burnt brick as speculated in Class A.

The building model is designed according to the IS specifications, IS:456:2000 and IS:800:2007 is used for concrete design and steel design respectively. The dead and live loads are in accordance with IS:875 Part-1 and Part-2. The earthquake load (seismic load) is considered as per 1893 (Part 1). The loads due to the earthquake are computed by static method. The soil properties of the defined type were considered from Joseph E. Bowles's "FOUNDATION ANALYSIS AND DESIGN".

Table 1: Height and Elevations of storey's

Floor Level	Height (in mts)	Elevation (in mts)
10th Floor	3.0	30.0
9th Floor	3.0	27.0
8th Floor	3.0	24.0
7th Floor	3.0	21.0
6th Floor	3.0	18.0
5th Floor	3.0	15.0
4th Floor	3.0	12.0
3rd Floor	3.0	9.0
2nd Floor	3.0	6.0
1st Floor	3.0	3.0
Ground Floor	0	00

A. MODELLING

The G+10 storied building is modelled using SAP 2000 software, the whole R.C framed structure is modelled as 3-D model. The elements of the structure like beam and column are modelled using reinforced cement concrete as 3-dimensional beam elements with 6 degree of freedom system at each of the node. And the slab element is modelled as membrane infinitely semi-rigid in its own plane to perform diaphragm action to transferee the upcoming horizontal loads to columns.The 3-D reinforced concrete beam elements were adopted for the modelling of the frame structure.

The R.C framed sections used in the modelling includes beams and columns. The beam section of size 300mm x 500mm, and the column section of size 350mm x 600mm is used in the modelling of the structure. The elements of structure like beam and column are made of M30 grade concrete and HYSD 415 grade steel.

The slab element used in the modelling process as R.C shell element of single layer membranes with 150mm thick. And this shell elements helps to withstand against the action of shear force and the bending moment and this slab is assumed as semi-rigid elements while modelling of the buildings.

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Table 2: Parameters of the developed RC models

Sl. NO	Parameters	Remarks
01	Structure type	G+10
02	Total No. of stories	11
03	Total height of building from GL to terrace	30.0 m
04	Size of beam	300 x 500mm
05	Size of column	350 x 600mm
06	Thickness of slab	150 mm
07	Thickness of wall	230 mm thick
08	Typical storey height	3.0 m
09	Grade of concrete for structural components	M30
10	Grade of steel	HYSD 415
11	Density of concrete	25 kN/m^3
12	Density of infill bricks	18 kN/m^2
13	Live load on floor	4 kN/m^2
14	Floor Finish on all floors	1.5 kN/m^2
15	Live load on roof	1.5 kN/m^2
16	Floor Finish on all roof	1 kN/m^2
17	Soil type	Soft, Medium and Hard
18	Response reduction factor	3.0
19	Zone and zone factor	V (0.36)
20	Importance factor	1.0
21	Damping	5%

Table 3: Properties of soil

Type of soil	Properties	
	Elastic Modulus, E in N/ mm^2	Poisson's ratio, μ
Type I- Soft	15	0.20
Type II- Medium	32.5	0.25
Type III- Hard	75	0.25

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B. Building with Fixed Base

The fixed base structure, it is also called as moment connection where the term moment refers to the building loading and the placement of the columns are done according to the layout of the ground floor plan of the building. Every one of the places of the columns will consist of the co-ordinates of ux, uy, uz, rx, ry and rz for fixed base conditions, and that implies there is no linear displacements and rotational displacements are allowed in the foundation.

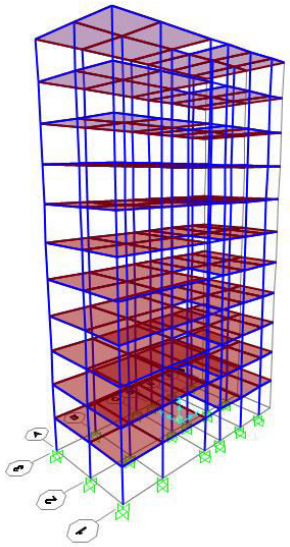

Fig. 1. 3-DView of the Building with Fixed base

C. Building with Raft foundation

Raft foundation of size 19 x 11 x 1.5m has been modeled in this project, the foundation was modeled using reinforced concrete thick shell elements to facilitate the SSI effects for the soft, medium and hard type of soils. For this building raft foundation is adopted and modeled.

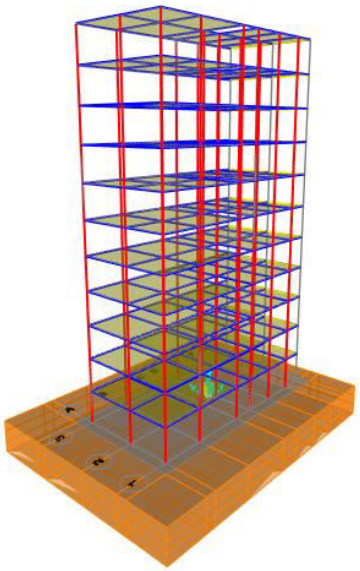

Fig. 2. 3-D View of the Building with Raft foundation

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V. RESULTS AND COMPARISON

The seismic reaction for the building with having fixed base and flexible base in various soil conditions has been analysed and compared with respect to lateral displacement, storey drift ratio, base shear, axial force, column moment, and natural time period of the building models with fixed base and flexible base for soft, medium and hard types of soils with raft foundation. And the results obtained are shown below.

A. Lateral Displacement

The effect of SSI, especially for the high-rise structures which is resting on soft soil may significantly amplify the lateral displacement. This amplification of the lateral displacement may change the performance level of the building frames.

Table 4: Lateral Displacement Results for Fixed and Flexible base

Storey Name	Fixed Base (mm)			Flexible Base (mm)		
	Soft soil	Medium soil	Hard soil	Soft soil	Medium soil	Hard soil
1st Floor	11.04	9.38	7.48	149.42	79.96	45.38
2nd Floor	23.28	19.40	14.96	158.32	86.69	52.35
3rd Floor	35.73	29.59	22.53	167.20	93.51	59.00
4th Floor	47.97	39.59	29.95	176.26	100.45	65.57
5th Floor	59.72	49.19	37.06	185.37	107.41	71.94
6th Floor	70.65	58.11	43.65	194.29	114.14	77.95
7th Floor	80.39	66.05	49.51	202.64	120.38	83.38
8th Floor	88.51	72.67	54.42	210.06	125.81	87.98
9th Floor	94.55	77.62	58.10	216.13	130.12	91.47
10th Floor	98.22	80.69	60.43	220.26	132.88	93.77

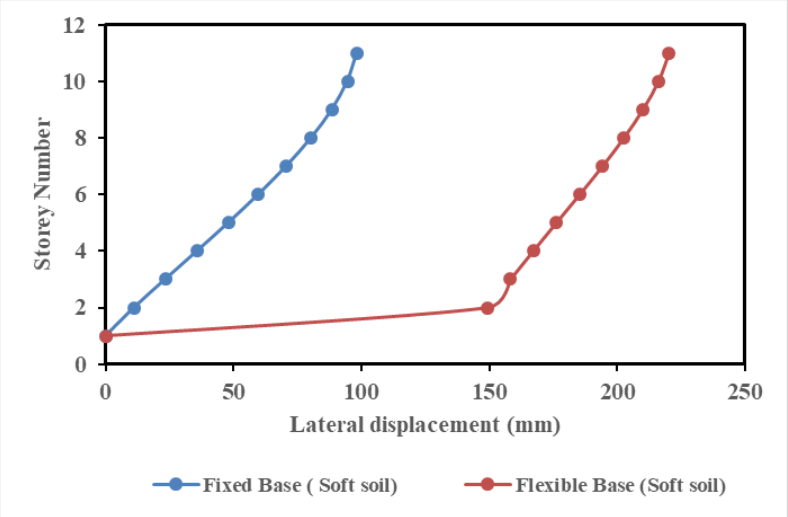

Fig. 3. Lateral Displacement comparison for Soft soil condition

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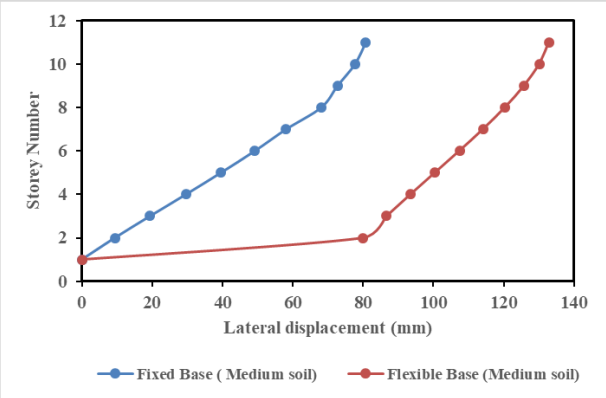

Fig. 4. Lateral Displacement comparison for Medium soil condition

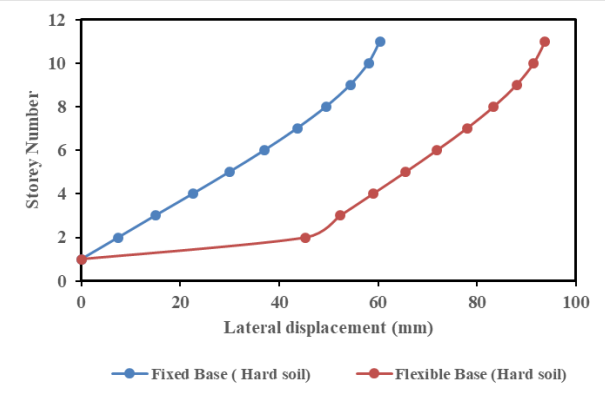

Fig. 5. Lateral Displacement comparison for Hard soil condition

B. **Storey Drift**

Storey drift is the deflection of the one storey concerning the other storey, immediately above or beneath. The storey drift of the purposed building on fixed base and flexible base in various soil conditions with raft foundation are analysed and the values obtained are tabulated in the below Table 5.

Table 5: Storey Drift Results for Fixed and Flexible base

Storey Name	Fixed Base (mm)			Flexible Base (mm)		
	Soft soil	Medium soil	Hard soil	Soft soil	Medium soil	Hard soil
1st Floor	10.02	8.44	6.60	27.97	20.27	17.75
2nd Floor	13.83	11.50	8.88	16.95	12.63	10.04
3rd Floor	14.19	11.85	9.10	15.12	11.25	8.97
4th Floor	13.99	11.68	8.98	14.62	10.83	8.69
5th Floor	13.50	11.27	8.69	14.12	10.44	8.39
6th Floor	12.68	10.61	8.19	13.39	9.86	7.93
7th Floor	11.49	9.63	7.48	12.33	9.05	7.27
8th Floor	9.85	8.30	6.50	10.90	7.94	6.37
9th Floor	7.72	6.56	5.22	9.06	6.52	5.21
10th Floor	5.15	4.47	3.68	6.93	4.91	3.85

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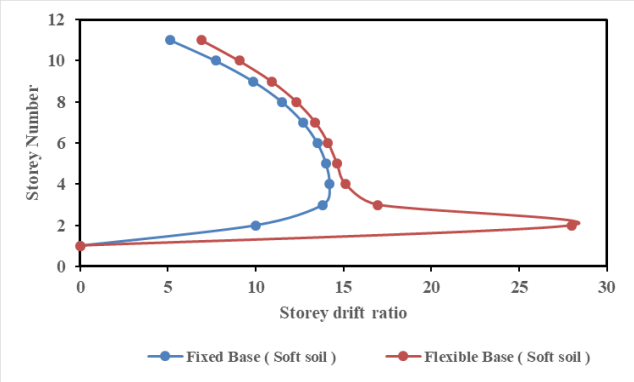

Fig. 6. Storey Drift ratio comparison for Soft soil condition

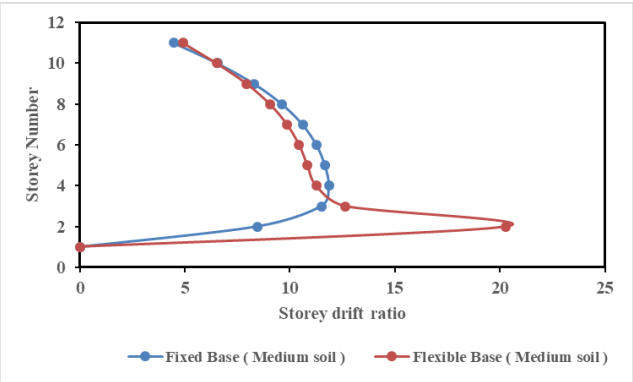

Fig. 7. Storey Drift ratio comparison for Medium soilcondition

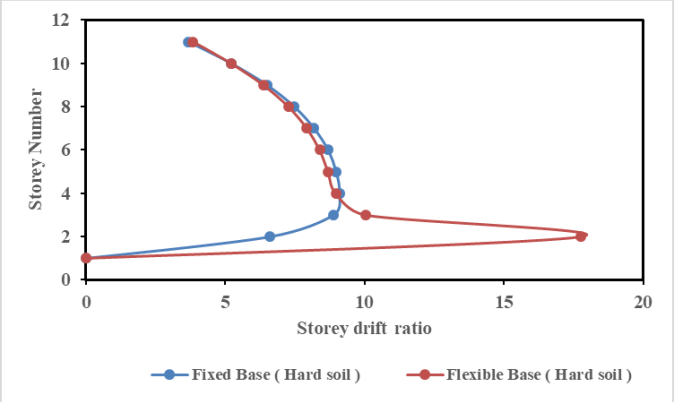

Fig. 8. Storey Drift ratio comparison for Hard soil condition

C. Base Shear

Due to Earthquake (seismic) activity on the structure the maximum base shear occurs at the base of the structure. And it can be impacted by the movements of the ground during earthquake concerning different soil conditions. The base shear for fixed and flexible base by considering SSI was analysed and the maximum base shear values obtained are tabulated below in Table 6.

Table 6: Maximum Base Shear Results for Fixed and Flexible base

Type of soil		Base Shear in (KN)
Fixed Base	Soft soil	3094.74
	Medium soil	2393.47
	Hard soil	1745.66
Flexible Base	Soft soil	3142.16
	Medium soil	2453.74
	Hard soil	1764.83

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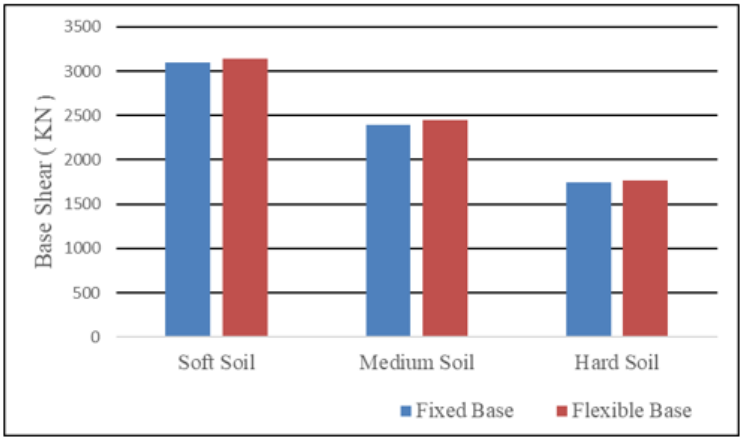

Fig. 9. Maximum Base Shear comparison with Fixed and Flexible base

D. **Axial Force**

The axial force is the force, which acts toward the axis of the body. This force may be either in tensile or compressive. The axial force for fixed and flexible base with soil structure interaction was analyzed and the values obtained are tabulated below in Table 7.

Table 7: Axial Force Results for Fixed and Flexible base

Type of soil		Axial Force in (KN)
Fixed Base	Soft soil	5812
	Medium soil	5772
	Hard soil	5642
Flexible Base	Soft soil	5122
	Medium soil	5332
	Hard soil	5522

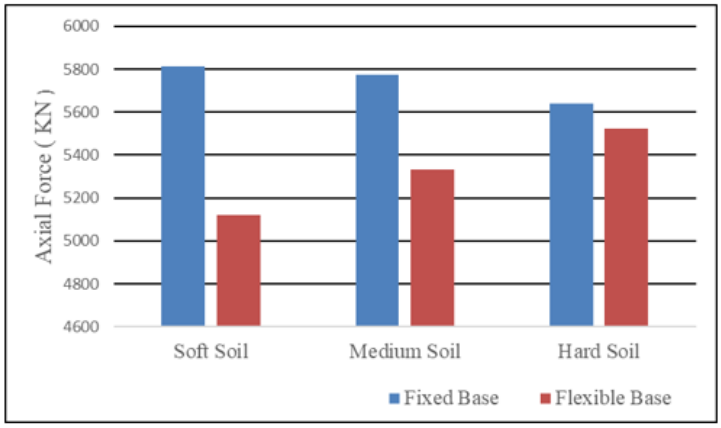

Fig. 10. Axial Force comparison with Fixed and Flexible base

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E. **Column Moment**

The column moment is the force, which is acting exactly along the axis of the column- column is concentrically loaded. And in this case, we often some account of buckling which results in deformation. The column moment for fixed and flexible base with soil structure interaction was analysed and the values obtained are tabulated below in Table 8.

Table 8: Column Moment Results for Fixed and Flexible base

Type of soil		Column Moment in (kNm)
Fixed Base	Soft soil	153.45
	Medium soil	135.09
	Hard soil	105.04
Flexible Base	Soft soil	395.49
	Medium soil	318.36
	Hard soil	219.73

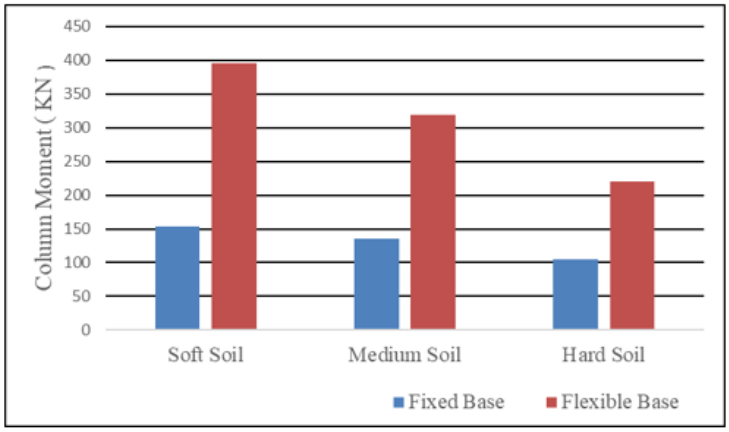

Fig. 11. Column Moment comparison with Fixed and Flexible base

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F. Natural Time Period

Natural time period is the important factors, which affect the seismic behaviour of the building. Natural time period of the structure is the time taken by the structure to complete one cycle of oscillation. The infinite number degree of freedom and the natural frequencies were taken into consideration while analysis. The time period for fixed and flexible base with soil structure interaction was analysed and the values obtained are tabulated below in Table 9.

Table 9: Time Period Results for Fixed and Flexible base

Mode No	Time period [sec]	
	Fixed Base	Flexible Base
01	4.051	5.005
02	3.244	3.899
03	3.102	3.705
04	2.319	2.625
05	2.023	2.220
06	1.962	2.135
07	1.952	2.121
08	1.797	1.908
09	1.774	1.877
10	1.726	1.811

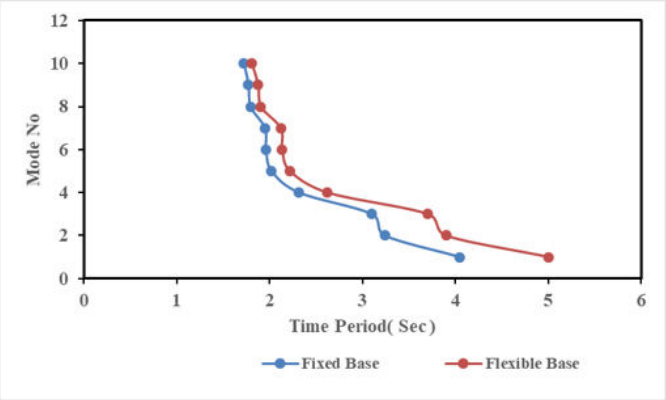

Fig. 12. Time period comparison with respect to mode numbers for Fixed and Flexible base

VI. CONCLUSION

The G+10 storied building R.C frame with fixed base system and flexible base system which is exposed to earthquake (seismic) forces were analysed and designed for soft, medium and hard type of soil conditions. The seismic reaction of the structure frames, for example Storey drift, Lateral displacement, Base shear, Axial force, column moment and Natural Time Period's values were determined and compared for fixed and flexible base type of the building frames.

- The lateral displacement in case of fixed and flexible base was compared. The maximum displacement was found in storey 10 and the minimum displacement was found in storey 1. Comparing both the cases the fixed base buildings displacement was viewed as lower than the flexible base building in different soil conditions. Comparatively, large amount of displacement was found in the flexible condition looked at to the fixed base.

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